

(54) Method for preventing rock failure in bottomhole formation zone

The invention relates to methods and devices intended for production of liquid and gaseous fluids including oil and gas and it can be used for construction of gas, gas condensate, oil and other vertical, inclined and horizontal wells in weak reservoirs. It ensures safe well operation at high output (exceeding critical output) due to the prevention of rock failure in the bottomhole formation zone. The method involves circulating fluid from the reservoir interval to be developed and in reverse direction; specifying the length of the interval to be developed and the transversal bottomhole dimensions; determining the value of the formation rock bond, the angle of internal reservoir rock friction, dynamic fluid viscosity factor, reservoir rock permeability factor, reservoir rock porosity factor and fluid density in normal conditions and in the bottomhole; applying forces perpendicularly to the bottomhole wall to provide effective mechanical compression stresses. Mechanical compression stress values are calculated from analytic expression. 1 cl.

Description of the invention

The invention relates to methods and devices intended for production of liquid and gaseous fluids including oil and gas and it can be used for construction of gas, gas condensate, oil and other vertical, inclined and horizontal wells in weak reservoirs.

A method is known allowing to prevent the penetration of rock particles into the well bottom during the filtration process involving circulating fluid from the reservoir interval to be developed and in reverse direction (USA Patent №6543545, class E21B 43/08, 2003). The known method consists of placing a device for retention of sand in a well in the way that an annular space appears between the device and the well wall; filling the annular space with a filtering medium followed by a radial expansion of the device for sand retention, which allows to decrease the volume of the annular space.

The drawback of the known method is impossibility of well operation at the output exceeding critical output, which causes rock failure in bottomhole formation zone.

A technical result provided by the method offered is the possibility of well operation at high output (exceeding critical output) due to prevention of rock failure in bottomhole formation zone.

The aforesaid technical result is attained due to the fact that in the present method for prevention of rock failure in bottomhole formation zone, during the process of filtration, in which fluid circulates from the interval to be developed and in reverse direction, the length of the reservoir interval to be developed is specified, the value of the reservoir rock bond, the angle of internal

reservoir rock friction, the dynamic fluid viscosity factor, the reservoir rock permeability factor, the reservoir rock porosity factor and fluid density in normal conditions and in the bottomhole are determined and forces are applied perpendicularly to the bottomhole wall to provide effective mechanical compression stresses. Mechanical compression stress values are calculated from the following formula:

$$\sigma > \frac{\mu \rho_0 Q}{2\pi k h \rho \left(\operatorname{tg}^2 \frac{\pi/2 + \varphi}{2} - 1 \right)} + \frac{4.21 \cdot 10^{-6} \rho_0^2 Q^2}{2\pi k \pi^2 h^2 \rho d \operatorname{tg}^2 \frac{\pi/2 + \varphi}{2}} - \frac{2C \operatorname{tg} \frac{\pi/2 + \varphi}{2}}{\operatorname{tg}^2 \frac{\pi/2 + \varphi}{2} - 1} \quad (1),$$

where

μ is a dynamic fluid viscosity factor, Pa·s;

ρ_0 is fluid density in normal conditions, kg/m³;

ρ is fluid density in bottomhole, kg/m³;

Q is well output, m³/s;

h is the length of the reservoir interval to be developed, m;

d is a transversal dimension of a bottomhole, m;

C is a value of reservoir rock bond, Pa;

φ is an angle of internal reservoir rock friction, rad;

k is a reservoir rock permeability factor, m²;

m is a reservoir rock porosity factor, dimensionless;

π is a number equal to circle length-to-diameter ratio.

In the case of gaseous fluid, its pressure and temperature in the bottomhole and the overcompressibility factor of gas are determined and the fluid density in the bottomhole is calculated from the following formula:

$$\rho = (239 \rho_0 P) / (101300 Z T) \quad (2),$$

and in the case of incompressible fluid, its density in the bottomhole is calculated with the formula

$$\rho = \rho_0 \quad (3),$$

where

ρ_0 is the fluid density in normal conditions, kg/m³;

ρ is the fluid density in the bottomhole, kg/m³;

P is the fluid pressure in the bottomhole, Pa;

T is the fluid temperature in the bottomhole, K;

Z is the gas overcompressibility factor, dimensionless.

In the process of pay drilling, mechanical unloading of the formation takes place in the direction perpendicular to the well wall. As a result, in porous rock effective radial mechanical stresses that are perpendicular to the bottomhole wall, i.e. stresses less fluid pressure in the bottomhole, decrease to zero on the bottomhole wall after pay drilling. Later on the effective radial mechanical stresses on the bottomhole wall are zero during well construction as well as during well operation. Farther from the bottomhole wall depthward into the formation, the effective radial mechanical stresses increase and reach the initial (before drilling) values. At the same time, the effective radial mechanical stresses along the axis of the bottomhole (longitudinal) and at a tangent to the bottomhole line (tangential) on the bottomhole wall change after drilling, however, they reach essential values. Thus, natural (before drilling) stressed-deformed state of the formation changes essentially.

In the bottomhole formation zone, this change increases during the well operation since at fluid intake the pressure in the bottomhole decreases, which leads to further change (decrease) in the total radial mechanical stresses in the formation close to the wall and to an increase in the difference between radial, longitudinal and tangential effective mechanical stresses. With an increase in a drawdown or output of a well, all the stresses reach their critical values and the bottomhole formation zone fails due to shift fault or stretching.

In the present invention, the main technical problem is solved by elimination of the main reason of the formation failure, i.e. a decrease in radial mechanical stresses, by applying forces perpendicularly to the bottomhole wall, which provide an increase of effective compression mechanical stresses to the values comparable to natural ones (before well-drilling). In this case, the stressed-deformed state of the formation, which was broken during the well construction, recovers partially or completely, and the initial (before drilling) ratio of longitudinal, tangential and radial effective mechanical stresses in the reservoir rock recovers as well.

The method is realized as follows. The length h (in meters) of the formation interval to be developed and the bottomhole transversal dimension d (in meters) are specified in accordance with the project of well construction, which takes into account geophysical investigations. The values of the reservoir rock bond C (in Pa) and the angle of internal reservoir rock friction φ (in radians) are determined by geomechanical tests, particularly by testing triaxial compression of reservoir rock core samples of the bottomhole formation zone. The values of the dynamic fluid

viscosity factor μ (in Pa·s) and the fluid density ρ_0 (in kg/m³) in normal conditions are determined with the use of the laboratory research data. In the case of gaseous fluid, its pressure P (in Pa) and temperature T (in K) in the bottomhole are determined with the help of gas-dynamic tests, for example, using a depth gage and thermometer; the overcompressibility factor Z of gas (dimensionless), which depends on fluid pressure and temperature in a bottomhole, is determined, for example, according to the method described in the book by A.I. Gritsenko, Z.S. Aliyev, O.M. Yermilov et al. Manual on well investigation. M.: Nauka, 1995, 523 p; the fluid density (in kg/m³) in a bottomhole is calculated from formula (2). In the case of incompressible fluid, its density in a bottomhole is determined from formula (3), it is similar to the density in normal conditions. The values of the reservoir rock permeability factor k (in m²) and the reservoir rock porosity factor m (dimensionless) are determined with the help of laboratory research data on rock core samples of the bottomhole formation zone and using the data of geophysical and gas-dynamic investigations of wells. The values of effective compression mechanical stresses σ are calculated with formula (1), and then forces are applied perpendicularly to the bottomhole wall using any known method, which enable to reach the effective compression mechanical stresses σ calculated with formula (1).

Nowadays, the presence of commercial expandable filters and a tool for their expansion provides technical operability of the invention offered.

The method offered provides well operation without failure of reservoir rock and at output exceeding significantly (in several times) the output, which is reached when known methods for preventing penetration of reservoir rock particles into a well bottomhole in the process of filtration involving circulating fluid from the reservoir interval to be developed and in reverse direction, since output restriction related to failure of reservoir is removed.

The use of the present invention enables well operation at high output (exceeding critical output).

Claims

1. A method for preventing rock failure in the bottomhole formation zone in the process of filtration involving circulating fluid from reservoir interval to be developed and in reverse direction, wherein the length of the reservoir interval to be developed and the bottomhole transversal dimension are specified; the value of the formation rock bond, the angle of internal reservoir rock friction, the dynamic fluid viscosity factor, the reservoir rock permeability factor, the reservoir rock porosity factor and the fluid density in normal

conditions and in the bottomhole are determined; forces are applied perpendicularly to the bottomhole wall to provide effective mechanical compression stresses, the values of which are calculated from the formula

$$\sigma > \frac{\mu \rho_0 Q}{2\pi k h \rho \left(\operatorname{tg}^2 \frac{\pi/2 + \varphi}{2} - 1 \right)} + \frac{4,21 \cdot 10^{-6} \rho_0^2 Q^2}{2m k \pi^2 h^2 \rho d \operatorname{tg}^2 \frac{\pi/2 + \varphi}{2}} - \frac{2C \operatorname{tg} \frac{\pi/2 + \varphi}{2}}{\operatorname{tg}^2 \frac{\pi/2 + \varphi}{2} - 1},$$

where

μ is a dynamic fluid viscosity factor, Pa·s;

ρ_0 is fluid density in normal conditions, kg/m³;

ρ is fluid density in bottomhole, kg/m³;

Q is well output, m³/s;

h is the length of the reservoir interval to be developed, m;

d is a transversal dimension of a bottomhole, m;

C is a value of reservoir rock bond, Pa;

φ is an angle of internal reservoir rock friction, rad;

k is a reservoir rock permeability factor, m²;

m is a reservoir rock porosity factor, dimensionless;

π is a number equal to circle length-to-diameter ratio.

2. A method for preventing rock failure in the bottomhole formation zone in the process of filtration involving circulating fluid from reservoir interval to be developed and in reverse direction according to claim 1, wherein in the case of gaseous fluid, its pressure and temperature in the bottomhole and overcompressibility factor of gas are determined, and the fluid density in the bottomhole is calculated with the formula

$$\rho = (239 \rho_0 P) / (101300 Z T),$$

and in the case of incompressible fluid, its density in the bottomhole is calculated from formula $\rho = \rho_0$,

where

ρ_0 is the fluid density in normal conditions, kg/m³;

ρ is the fluid density in the bottomhole, kg/m³;

P is the fluid pressure in the bottomhole, Pa;

T is the fluid temperature in the bottomhole, K;

Z is the gas overcompressibility factor, dimensionless.

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